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MODELING OF METEOROLOGICAL PARAMETERS FOR JORDAN

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BY

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To the Truly Incorruptible among Men, whose

Nobility Restores our Gratitude and Reverence

For Human Life

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LIST OF SYMBOLS AND ABBREVIATIONS

ACF	AutoCorrelation Function
AM	Amman Station
AQ	Aqaba Station
AR (p)	AutoRegressive p th Order Process
a and b	Parameters of Angstrom Equation (2.1)
a, b, c, d, e, f, g	Parameters of Equations (2.4 and 2.5)
and j	....
avg	Average
c and k	Parameters of Weibull Distribution Function
CDF	Cumulative Distribution Function
D	Maximum Difference Between Empirical and Theoretical Cumulative Distribution Curves
$D_{0.01}$	Critical Value of K-S test at 1% Significant Level
$D_{0.05}$	Critical Value of K-S test at 5% Significant Level
D.A	Dier Alla Station
E.P.F (K_E)	Energy Pattern Factor
EFF	Modeling Efficiency (equation 2.6)
F (v)	Probability Density Function of the Wind Speed (equation 3.2)
G_{SC}	Solar Constant (1367 Wm $^{-2}$)

h	Relative Humidity
H	Daily Global Solar Radiation (MJ/m^2)
$\overline{H}$	Monthly Mean Daily Global Solar Radiation (MJ/m^2)
H0	Daily Extraterrestrial Solar Radiation (MJ/m^2)
$\overline{H0}$	Monthly Mean Daily Extraterrestrial Solar Radiation (MJ/m^2)
IID	Independent and Identically Distributed Random Noise
IR	Irbid Station
K-S test	Kolmogorov-Smirnov Test
M (v)	Cumulative Distribution Function of the Wind Speed
m	Month
MSE	Mean Square Error
N	Number of Data Points
n	Day of the Year (n = 1, 2, …, 365 or 366)
obs	Observed Values
PACF	Partial AutoCorrelation Function
PDF	Probability Density Function
P	Power Density (W/m^2)
Q	Values of Ljung-Box Statistics
Q*	Values of McLeod and Li Statistics
R	Correlation Coefficient
R.M	Ras Monief Station
r_h	AutoCorrelation Coefficient at Lag h

r*	AutoCorrelation of the Squared Residuals (Equation 4.7)
S	Daily Actual Sunshine Duration (hour)
$\overline{S}$	Monthly Mean Daily Actual Sunshine Duration (hour)
S_0	Daily Maximum Possible Sunshine Duration (hour)
$\overline{S0}$	Monthly Mean Daily Maximum Possible Sunshine Duration (hour)
sim	Simulated Value
t	Index of Time Step
T	Range in Temperature Extremes (C^0)
v	Wind Speed (m/s)
var	Variance
WN	White Noise Process
X(t)	Observations of Stationary Time Series
Y(t)	Original Data of Time Series
y	Year
Z (t)	Uncorrelated White Noise Process with Mean Zero and Variance σ^2_z
χ^2 test	Chi- Square Test
δ	Solar Declination Angle
ϕ	Latitude of the Locations
$\phi_{h,h}$	Partial AutoCorrelation Coefficient at Lag h
$\phi_1, \phi_2 \ldots \phi_p$	Parameters of AutoRegressive p th Order Process

σ	Standard Deviation
σ^2	Variance
ω	Sunset Hour Angle
Γ	Gamma Function
ρ	Air Density (kg/m^3)

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

Modeling of Meteorological Parameters for Jordan

By

Mohammad Ahmed Alghoul

October 1999

Chairman : Prof. Hj. Mohd Yusof Sulaiman, Ph.D.

Faculty : Science and Environmental Studies

Jordan is a developing country with limited natural resources. It imports most of its energy for heating, electric power generation, and other uses. The limited energy sources consider renewable energy options such as solar, wind, and hydropower as alternatives. For successful energy research and applications, weather parameters (wind speed, sunshine duration, humidity. temperature, and global solar radiation) should be modeled.

For solar energy applications, information on global solar radiation are required for the country over a long period of time. Some sites have no records of solar radiation data. So, developing methods to predict solar radiation from any available weather data are necessary. Models based on Angstrom formula using data such as Sunshine, Temperature and Humidity of four stations are described.

Wind is an important energy resource and man has long sought to harness it. The calculation of the output of a wind machine requires knowledge of the distribution of the wind speed. Weibull distribution was applied to fit the probability distribution nature of wind speed. For all locations the wind speed data can be modeled easily by the Weibull distribution.

Time series analyses of the weather parameters such as wind speed, relative sunshine duration, relative humidity, range in temperature extremes, and relative solar radiation all as daily average were carried out. To apply AutoRegressive process, transformation technique (Differencing) was applied to generate stationary time series. Seasonal and non-seasonal AutoRegressive models of order p AR(p) were used to describe the weather parameters data for all stations.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk memperolehi ijazah Master Sains

Permodelan Parameter Kajicuaca untuk Jordan

Oleh

Mohammad Ahmed Alghoul

October 1999

Pengerusi : Profesor Hj. Mohd. Yusof Sulaiman, Ph.D

Fakulti : Fakulti Sains dan Pengajian Alam Sekitar

Jordan adalah sebuah negara membangun dengan sumber semulajadi yang terhad; kebanyakan sumber tenaga untuk pemanasan, penjanaankuasa elektrik, dan lain-lain kegunaan adalah diimport. Sumber tenaga yang terhad ini telah memaksa kita untuk menimbangkan penggunaan tenaga keterbaharuan seperti tenaga suria, angin, dan kuasa hidro sebagai alternatif. Untuk menjayakan penyelidikan tenaga serta untuk kegunaannya, parameter cuaca di Jordan (laju angin, tempoh sinaran matahari, kelembapan, suhu, dan sinaran suria global) perlu dimodelkan.

Bagi aplikasi tenaga suria, maklumat berkenaan sinaran suria global bagi kawasan tertentu di mana tiada rekod data cuaca adalah diperlukan. Model

berdasarkan formula Angstrom menggunakan data cuaca seperti sinaran matahari, suhu dan kelembapan untuk empat stesen adalah dibincangkan.

Angin adalah sumber tenaga penting dan manusia telah lama meneroka untuk menggunakannya. Pengiraan keluaran bagi mesin angin memerlukan pengetahuan tentang taburan kelajuan angin. Taburan Weibull telah dipadankan kepada taburan kebarangkalian perlakuan kelajuan angin. Untuk semua lokasi, data berkenaan boleh dimodelkan dengan menggunakan taburan Weibull.

Analisis siri masa ke atas parameter cuaca telah seperti kelajuan angin, sela sinaran relatif, kelembapan relatif, renj dalam suhu ekstrim dan radiasi solar relatif kesemuanya sebagai purata harian telah dilakukan. Untuk menggunakan proses auto regrasi, teknik transformasi (perbezaan) telah digunakan bagi menjana siri masa pegun. Model-model auto regrasi bermusim dan tidak-bermusim dengan tertib p AR(p) telah digunakan untuk menyatakan data parameter cuaca untuk semua stesen.

CHAPTER I

INTRODUCTION

Research, development and demonstration efforts in renewable energy entail frequent collections, analysis and transmission of information. Where information takes the form of numerical data, it is necessary to employ appropriate data analysis and representation techniques so as to ensure efficient information utilization. The main goal of meteorological research on utilization of solar energy is to be able to inform the projectors, producers, and users of solar technical installations, how much of solar energy is to be expected on the receiving surface of a certain orientation during a certain time period. Furthermore, to use solar energy, information on air temperature, wind, sunshine duration, relative humidity, etc, is also required. Global solar radiation is essential in the design and study of solar energy conversion devices. There are also other uses for such information including agricultural studies and meteorological forecasting.

Most of wind data models may be categorized into two types: descriptive statistics and probabilistic distribution models. The first category are graphs or power tables such as (speed histograms, speed or power duration curves and speed time plots), whereas the second takes the form of concise analytic expressions such as Weibull distribution. Majority of wind surveys contains both representations. Such representations, while in themselves useful summaries of data values, consist of transformed information and do not contain the real time element; they are unable to express wind speed dynamics explicitly in the time domain, a factor essential to operational analysis of wind power systems. Furthermore, these representations, apart from lending themselves to visual assessments, may not be adequate if indices or parameters are called for in comparative studies of data sets form, for example two sites or two periods of time. In fact, the need for a more appropriate model form arises in common cases where a potential site is so located that wind data are unavailable or insufficient: in such situations, techniques of data interpolation and extrapolation in space, in addition to forecasting in time, are necessary.

Some applications of statistical techniques to the meteorological parameters of Jordan are described in this thesis and it is hoped that these techniques can be more widely adopted to complement existing procedures.

Description of Climate of Jordan

Jordan lies between latitude 29 ^{0} 32 N - 32 ^{0} 42 N and longitude 35 ^{0} 00 E - 38 ^{0} 15 E. The country is bordered by Syria in the north, Saudi Arabia in the south, Iraq and Saudi Arabia in the east, Palestine in the west. The climate in Jordan is predominantly of the Mediterranean type. It is similar to the climate found in California USA, south east of Africa and south east of Australia. A hot dry summer and a cool wet winter characterize it with two short transitional periods in between. The first stands around mid November and the second stand around end of April. According to the topography of the country ["Jordan Climatological Data Handbook" (1988)], the climate of Jordan could be divided into three main types:

1- The hilly regions: They are characterized by their pleasant climate, they have cool dry summer and cold wet winter and the majority of the population of Jordan live in these regions. The altitude of the hilly regions ranges between 500-1000 m, reaching 1500 m in the southeastern hills.

2- The Ghor: Areas below mean sea level (M.S.L), in which the Jordan River and the Dead Sea lie. (Has an altitude ranging between 197 m below M.S.L in the north and 392 m below M.S.L at the Dead Sea). The weather in this region is very hot in summer and warm in winter.

3- The Desert: It lies in the eastern parts of the country and forms a part of the Syrian Desert. It is characterized by its clear sky during most of the year, it has hot dry summer and cold winter with very little precipitation.

The geographical locations of the four towns together with map of Jordan are shown in table 1, and figure 1 respectively.

Sunshine

Jordan is a high insolation country. The number of sunshine hours amount is almost to about 3000 hours per year. Such weather is most favorable for the utilization of solar energy.

Temperature

The temperature varies from one place to another, also from one season to another. On the whole the temperature has a close relation with the various zones.

Humidity

The humidity is generally above 80% during the winter, and is generally low averaging around or less than 50% during the summer.

Wind

Jordan is mainly influenced by two wind systems:

- The northwest during summer and this is due to the dominance of the seasonal trough over Iraq, north Syria, and extending to Cyprus. This trough is an extension of the Indian monsoon trough.
- The SW-WLY wind during winter, and this is due to the travelling depressions along the Mediterranean and the Cyprus depression, which have their centers in the vicinity of Cyprus.

Rainfall

Rain falls mainly in the winter with heavy fall in January and February, but the beginning of rainfall is in October or sometimes in late September; it ends in mid may and some times a little earlier. This depends entirely on the weather conditions of the particular year. The annual mean rainfall has a close relation